2015 Storm-Scale Ensemble Design Workshop
24-25 July 2015, ESRL/GSD, Boulder CO

Introduction

In late July 2015, a two-day workshop was held in Boulder Colorado to discuss the current state of storm-scale numerical weather prediction. The workshop attendees included many of the major stakeholders in convective-scale prediction research and operations within the U.S. weather enterprise. The workshop identified several of the outstanding issues regarding implementation of these ensembles and then attempted to recommend a set of research priorities that would help the planning process for operational convective-scale ensemble prediction at NCEP. The workshop also discussed how the current plans for convective-scale ensembles using 3 km grid resolution would eventually lead to NOAA's ultra-high resolution Warn-on-Forecast system for the mid-2020's.

The workshop was attended by approximately 40 scientists from NCEP, NOAA's ESRL and NSSL laboratories, NCAR's Image and MMM groups, OU's Center for the Analysis and Prediction of Storms, as well as other scientists from Oklahoma, Texas Tech, and Penn State universities. See the attendee list in Appendix A.

The goal of the workshop was ambitious: to define a set scientific and technical issues regarding the design and implementation of ensemble-based convective-allowing data assimilation and prediction. The hope was that various research groups would then address some of these issues as part of their own research efforts. Results will help guide NCEP's decision making process as it moves toward operationalizing such as system over the next 5 years.

The purpose of the executive summary is to document a) the major issues that were discussed, b) where the various groups agree on the research priorities and issues, and c) where there was no consensus reached. As the executive summary will show, there are many places where there was strong agreement between the various groups. Areas of disagreement were often associated with operational resource constraints, although there are clearly several fundamental scientific issues to be resolved over the next decade.

All the participants expressed the opinion that they found the workshop very useful and that that another workshop focused on storm-scale verification should be held in the next year or so. There was also strong agreement that storm-scale ensembles evaluated within NSSL's spring forecast experiment should be coordinated at a higher level to provide guidance as to the composition and tuning of the forthcoming HREF ensemble at NCEP.

Louis Wicker, NOAA/NSSL
David Dowell, NOAA/GSD
Therese Ladwig, NOAA/GSD & CIRES

Executive Summary

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1. Overall Recommendations

Storm-scale Ensemble of Opportunity (SSEO)

- The SSEO should be operationalized at NCEP *(strong agreement)*
- Ensemble should be ~O(10) in size, split between ARW and NMMB cores *(strong agreement)*
- Committee should be formed from model developers and users (SPC, NWS) to specify each core's characteristics for the ensemble membership and to standardize how models are run *(strong agreement)*
- Unclear how or WHAT to improve from SSEO forecasts with respect to operation forecasts of severe convection *(moderate agreement)*

HRRRe/HREF

- Multiple core (ARW and NMMB) can be used as an initial implementation without ensemble data assimilation for next several years *(moderate agreement)*
- An ensemble data assimilation system will require a single core in order to facilitate model improvement and the ensemble data assimilation. *(strong agreement)*
- Not clear which core will eventually be used for 3 km (ARW, NMMB, or new NGGPS core?)
- Not clear when HREF ensemble DA can be implemented at NCEP due to computational resources (GSD thinks ~2-3 years, EMC thinks ~5-6 years). Part of this uncertainty is associated with an uncertainty of the number of members (10 or 50?) required for accurate ensemble DA and probabilistic forecasts is unclear *(poor agreement).*

WoF

- WoF system will require an hourly accurate background from 3 km HREF to initialize the hybrid multi-resolution Warn on Forecast system initially at 1 km resolution *(moderate agreement)*
- 1 km WoF ensemble will require resources that may not be available till ~mid-2020s.
- WoF a regional ~O(1500 km^2) application *(moderate agreement)*
- WoF will be an on-demand forecast similar to HWRF *(moderate agreement)*
- WoF will produce forecasts several times per hour *(strong agreement)*

Other

- EMC suggested that another workshop be held to define forecast metrics for SSEO, HRRRe, and HREF systems to evaluate system performance *(strong agreement)*
- The community would benefit from a far more COORDINATED effort to identify ways to determine best practices for ensembles and ensemble DA. This is probably a critical issue to push over the next 2-3 years. *(moderate agreement)*

2. Science Summary

Models

- Reduction of model errors should be the highest priority of model developers over the next few years, particularly focused on PBL and microphysical schemes.
- Model improvements are likely to come from running single physics systems that are continuously cycled. Multi-core, multi-physics (and multi-background ICs) systems that are designed to increase ensemble spread also hide model biases making it very difficult to detect and correct model errors.
- Need to understand biases in storm-motion in ensemble-based DA systems over next year.
- Resolution of 1 km or higher will be needed to begin to predict evolution of individual storm characteristics, such as rotation trend, QPF, and severe winds.

Data assimilation

- Multiscale data assimilation is not a well-understood problem and presents a number of practical issues. More attention needs to be focused on this issue.
- Hybrid techniques at convective scale are showing promise for single resolutions and should be tested using a higher resolution control member.
- A continuously cycled mesoscale analysis system (NCAR, Romine) is possible and has helped reduce the model physics errors over the past 3-4 years.
- Need to improve stochastic forcing at convective scales to improve ensemble reliability and spread.

Forecast & Verification

- For SSEO-type applications (12-36 hour forecasts), neighborhood methods appear to provide useful information for probabilistic forecasts for severe weather threats

- Object-based methods will be useful to identifying systematic biases in model prediction of various phenomena, particularly individual convective storms (e.g., the apparent downstream phase speed error).

Other

- Need to focus efforts on what is wrong with SSEO-type applications and the individual model cores that comprise this ensemble (what is the low-hanging fruit) to help focus model improvements.
- Need to consider carefully what can and cannot be forecasted specific grid resolution, especially the targeted 3 km and 1 km grids, especially with respect to identifying grid-scale weather threats
- To reduce model errors and improve best practices, groups need to consider coordinating their real-time efforts by using similar models, grids, and IC/BC's

Appendix A: Workshop Participants

ESRL	**NSSL**	**NCAR**
Trevor Alcott Curtis Alexander Jeff Beck Stan Benjamin John Brown David Dowell Isidora Jankov Terra Ladwig Jeff Whitaker	Adam Clark Mike Coniglio Jidong Gao Kent Knopfmeier Corey Potvin Dusty Wheatley Lou Wicker Nusrat Yussouf Pat Skinner Lou Wicker Jack Kain	Jeff Anderson Glen Romine Ryan Sobash Chris Snyder
EMC	**OU**	**CAPS**
Jacob Carley Geoff DiMego Walter Kolczynski	Xuguang Wang Aaron Johnson	YoungSun Jung
SPC	**PSU**	**TTU**
Israel Jirak	Dave Stensrud	Brock Burghardt Aaron Hill
NCEP		
Bill Lapenta		